Recent Trends in Power System

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Abstract- This paper is intendto the power system which includes generation, transmission and distribution of the electrical energy. This gives the overview of generation which tells about the recent energy production in the world. It explains about the production of energy and source of energy of top 20 countries in the world, also gives the statistical data about the sources available in India and other countries. The overall electrical energy review in 2015also explained here. Electrical energy transmission tells about the recent trends present in it and transmission development issues also given here. It tells about the future expansion in transmission system and the reason for going into increasing the voltage level high. The investment in the transmission system also explained here. The only one control system for the five national regions of grid is present in Gurgaon it is named as NTAMC. This also explains the energy distribution present in India with the recent technology includes smart grid, SCADA …etc. Additionally it tells about the POSOCO with PGCIL and the improvement in the power system by implementing the smart grid very effectively in India.

***Index Terms*-** OECD – Organization for Economic Co-Operation and development, TWh-Terawatt-hour, ckm–circuit kilometers, O&M-Operation and maintenance.

I. Introduction

Electrical Energy is the basic economic development of a country. Energy exists in different forms in nature but the most important form is the Electrical energy. In this modern society use of electrical energy has become a part and parcel of our life.

An electric power system is a network of electrical components used to generate,supply (distribute), transfer (transmit) and use electrical energy. Heregrid plays an important role in supplying uninterrupted supply to all the regions in our country. Grid interconnects all the five regions of our country and now it has been made into one grid, one nation, and one frequency in India.

Though we generate only 11KV from the generating side it is not sufficient to transmit the power. So we go for transmission where increasing of high voltages in HVAC, HVDCtransmission system. Then we distribute the power to the consumer's by reducing the voltage levels. Recently the generation of power is increased drastically India using coal and wind energy. In transmission we go for high voltage transmission to reduce loss i.e., I^2R losses and corona. The transmission of high voltage exists in India is till 765KV transmission. This transmission made very sophistication by introducing the SCADA systems into the transmission system. The SCADA system makes the man work more easier way where in control room only two PC are present where the all available data's are feed into it. In few years, there is a vast development in the generation and transmission of energy in India.

II. Energy Production

The energy is produce from the generating stations using the available resources either renewable or non-renewable sources. The world's total production of electrical energy is 23,536,500 GWh* till 2014*. In this India stands third largest electricity production in the world. It produces about 1,208,400 GWh* till 2014*.

The following table represents the top 20 electricity producing countries 2014*/2015*,

Rank	Country/Region	Electricity production (GWh)	Date of information
N/A	*World Total*	23,536,500	2014[1][2]
N/A	*European Union*	3,166,000	2014[1]
1	China	5,810,500	2015[3]
2	United States	4,297,300	2014[1]
3	India	1,208,400	2014[1]
4	Russia	1,064,100	2014[1]
5	Japan	1,061,200	2014[1]
6	Canada	615,400	2014[1]
7	Germany	614,000	2014[1]
8	Brazil	582,600	2014[1]
9	France	555,700	2014[1]
10	South Korea	517,800	2014[1]
11	United Kingdom	356,800	2013[2]
12	Mexico	293,600	2013[2]
13	Saudi Arabia	292,200	2013[2]
14	Italy	288,400	2013[2]
15	Spain	285,300	2013[2]
16	Turkey	264,100	2015[4]
17	Iran	263,400	2013[2]
18	South Africa	256,100	2013[2]
19	Taiwan	252,000	2013[2]
20	Australia	244,800	2013[2]

Electricity2015 in review- World electricity generation grew by 0.9% in 2015, slightly below the growth of primary energy (1.0%)Growth was down on 2014 (2.4%) and remained well below the 10-year trend (2.8%). OECD electricity grew by 0.2%, after four consecutive years of declining generation. Non-OECD electricity generation grew by 1.4%, significantly slower than 2014 (4.9%) and well below the 10-year trend (5.5%). The slowdown was most marked in China, the world's largest electricity generator, with growth of just 0.3% in 2015, compared to 6.7% in 2014. The world's second largest generator, the US, posted a decline of 0.1%, and North America was the only region to show a decline in electricity generation (-0.1%). India, the third-largest generator, grew by 4.1% to record the largest volumetric growth in generation.

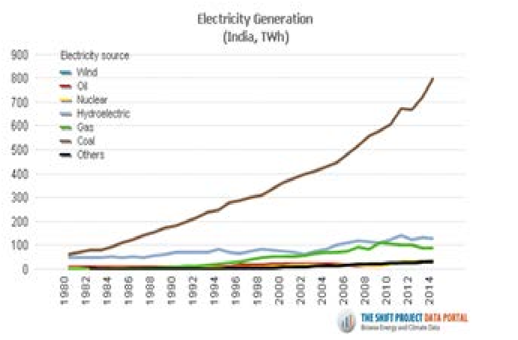
Growth was slightly up on 2012 (2.2%) but remained below the 10-year trend (3.3%) faster than 2013 (4.3%) but well below the 10-year trend (6.3%). Electricity generation grew in all regions except Europe & Eurasia, where it declined by 1.6%. China (+4.0%) and the US (+0.7%) remain the largest and second largest electricity generators, India (+9.6%) is third while

Russia (+0.5) overtook Japan (-2.4%) in 2014 to take fourth place.

Electricity generation in India:

There are various renewable and non-renewable resources present in India. They are wind, oil, nuclear, Hydroelectric, Gas, Coal…etc. In the last decade there is an increase in the generation of electricity using coal as a source and next wind energy falls the second in its generation followed by the gas.

The following graph represents the statistical data of electricity generation,

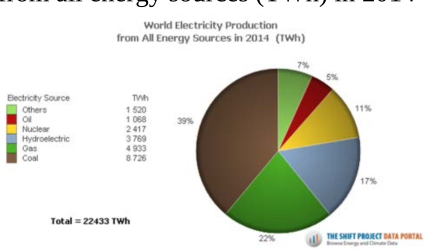


Production and sources of the top 20 countries in the world,

Country	Electricity production (TWh)	% Coal	% Natural gas	% Oil	% Hydropower	% Other renewable	% Nuclear power
Argentina	129.6	2.5	51.4	15.1	24.4	1.7	4.9
Australia	252.6	68.6	19.7	1.6	6.6	3.5	0
Austria	62.2	11.8	19.9	1.6	55	10.7	0
Canada	636.9	12	9.8	1	59	3.3	14.7
Chile	65.7	29.9	20.9	9.7	32	7.6	0
China	4,715.7	79	1.8	0.2	14.8	2.2	1.8
Hong Kong SAR, China	39	71.2	28.5	0.3	0	0	0
Denmark	35.2	39.7	16.5	1.3	0	40.2	0
Egypt	156.6	0	74.7	15.8	8.3	1.3	0
Finland	73.5	14	12.9	0.6	16.9	15.9	31.6
France	556.9	3.1	4.8	0.6	8	3.6	79.4
Germany	602.4	45.1	13.9	1.1	2.9	17.6	17.9
Iceland	17.2	0	0	0	72.7	27.3	0
India	1,052.3	67.9	10.3	1.2	12.4	5	3.2
Indonesia	182.4	44.4	20.3	23.2	6.8	5.2	0
Iran	239.7	0.2	66.8	27.8	5	0.1	0.1
Iraq	54.2	0	62.1	12.9	7.6	0	0
Israel	59.6	59	33.1	7.3	0	0.4	0
Italy	300.6	16.7	48.1	6.6	15.2	12.4	0
Japan	1,042.7	27	35.9	10.1	8	4.2	9.8

Here from the above table we can see that India places 14th among source available countries which produces 1,052.3TWh of electricity. The sources available in India are 67.9% of coal, 10.3% of Natural gas, 1.2% of oil, 12.4% of Hydropower, 5% of other renewable sources.

The following chart represents the world electricity production from all energy sources (TWh) in 2014



Energy transmission:

Electric power transmission is the bulk movement of electrical energy from a generating site, such as a power plant, to an electrical substation. Electricity is a concurrent subject in India i.e., both the central and state governments

are responsible for the development of the electricity sector. NTPC, NHPC, THDC, NEEPCO, SJVNL, NLC etc. are the central generation utilities and POWERGRID is the Central Transmission Utility. At the State level, there are Gencos and Transco in the respective States. The country has been demarcated into five electrical Regions viz. Northern (NR),

Eastern (ER), Western (WR), Southern (SR) and North Eastern (NER). However, NR, ER, WR and NER have been synchronously interconnected and operating as singlegrid – Central Grid (capacity about 110,000MW). The Southern region isasynchronously connected to the Central Grid through HVDC links.

The backbone transmission system in India is mainly through 400 kV AC network with approximately 90,000 circuit kilometers (ckm. (=2xroute km)) Of line length. Highest transmission voltage level is 765kV with line length of approximately 3120 ckm. There are about 7,200 ckm of 400 kV systems, 5500 MW, +/- 500 kV long distance HVDC systems, an HVDC Monopole of 200 MW and four HVDC Back-to-Back links of 3000MW capacity. These are supported by about 1,23,000 ckm. of 220kV transmission network. As mentioned above, all the five regions are interconnected through National Grid comprising hybrid AC/HVDC system. Present inter-regional transmission capacity of the National Grid is about 20,800 MW.

Transmission System Development Issues

As mentioned above, in order to meet growing requirement, development of strongtransmission system between pit-head/resource generation complex and bulkconsumption centers are required. However, development of transmission systeminvolves following issues:
- Minimization of Right of Way
-Protection of flora & fauna, wild life
-Creation of long distance high capacity transmission corridors to enableminimum cost per MW transfer as well as Optimal Transmission losses
-Minimal Impact on Environment
-Strengthening of National Grid

Future Plan in Transmission:

In order to address above issues, high capacity transmission corridors comprising765kV AC and ±800kV 6000MW HVDC system along with 400kV AC and±500kV/600kV 2500Mw/6000MW have been planned to facilitate transfer of powerfrom remotely located generation complexes to bulk load centers.

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Transmission Lines	Addition by 2012 (Ckm)	Addition by 2017 (Ckm)
765 kV	7,612	25000-30000
HVDC Bipole	11,078	4000 - 6000
400 kV	1,25,000	50000
220 kV	1,50,000	40000
Total	2,93,852	119,000 – 126,000
Substations	**Addition by 2012**	**Addition by 2017**
HVDC	14,700 MW	16,000 -22,000 MW
765 kV	53,000 MVA	1,10,000 MVA
400kV	1,45,000 MVA	80,000 MVA
220 kV	2,30,000 MVA	95,000 MVA
Total Capacity	4,28,000MVA	2,85,000MVA
Inter Regional Transfer Capacity	38,000 MW	75,000 MW

Increase in voltage:

In order to optimize right-of-way, high density transmission corridors (MW per meterROW) either by increasing voltage level or current order or both i.e. increase involtage and current are need to be developed.

Power intensity at different voltageLevel is tabulated in Tablebelow:

High Density Transmission Corridor:

Voltage	132 kV	220 kV	400 kV	765 kV	+500 kV	+800 kV (approx.)	1200 kV (approx.)
ROW Meters(M)	27	35	46	64	52	70	90
Capacity (MW)	Upto 70-80	Upto 160-170	Upto 600-700	Upto 2500-3000	Upto 2000-2500	Upto 6000-6400	Upto 6000-8000
MW/m	3	5	15	45	48	90	90

Towards development of high intensitytransmission corridor, there is a plan to develop ± 800 kV, 6000 MW HVDC system asa part of evacuation of bulk power from North Eastern Region (NER) to NorthernRegion (NR) over a distance of around 2000 kms. In addition, increasing the ACvoltage level at 1200kV level has been planned. It is to mention that we are aimingtowards use of 1100kV equipment's for 1200kV operation by optimizing their protectivelevel with the help of high energy level Surge arrester so as to achieve economy in respect of 1200kV UHV system development. Research work for 1000kV HVDCsystem has also been commenced.

Upgradation of transmission line:

POWERGRID has successfully implemented upgrading of 220kV D/C KishenpurKishtwarline in J&K to 400 kV S/c first time in India. It has resulted in increase ofpower transfer intensity of the transmission corridor with marginal increase in ROW(from 35m to 37m) but far less than standard 400kV line (46 m). Upgradation of 400kVD/C lines to 400/±500kV HVDC bipoles are also under exploration.

Upgradation of HVDC Terminal:

POWERGRID has been seamlessly upgraded ±500kV Talcher(ER) – Kolar(SR)HVDC terminal from 2000MW to 2500MW without changing of any equipment. Thathas been achieved with enhanced cooling of transformer and smoothing reactor withmeager cost. The payback period is about 2-3 years.

1200kV Test Station:

In order to increase the power density of the corridor, development of 1200kV ACsystem as next higher AC voltage level has been decided. However, 1200kV ACtechnology is relatively a new one in the world. Therefore, to develop this technologyindigenously, a unique effort has been made by POWERGRID through a collaborativeresearch between POWERGRID and Indian manufacturers to establish a 1200kV UHVAC Test Station. This endeavor shall benefit the Indian Power sector andmanufacturers as availability of 1200KV class equipment within country will not onlyenable optimization of transmission cost, but also help in during O&M phase. In this direction, POWERGRID along with Indian manufacturers is establishing a 1200kVUHVAC Test Station at BinaIin the State of M.P) where a 1200KV test line (S/c+D/c) isbeing constructed along with two nos. 1200KV test bays in which the leadingmanufacturers are providing main equipment like transformers, surge arresters, circuitbreakers, CTs, CVTs and transmission line hardware etc. POWERGRID shall provide

Space, civil foundation, 1200kV line, control & protection system, various testingequipment, auxiliaries & fire protection system, 1200kV bushing etc. These test baysand test line shall be used by the manufacturers and POWERGRID for various fieldtests so that the results and feedback can be used for developing field provenequipment of 1200kV system in India as well as gain initial operational experience.Development of this test station is in advance stage and likely to be commissioned by 2010.

Investment in Transmission:

The Estimated total fund requirement for transmission by 12th Plan i.e. 2016-17 hasbeen assessed as USD 42 Billion.

Inter-State Sector	USD 21 Billion
State Sector	USD 21 Billion

NATIONAL TRANSMISSION ASSET MANAGEMENT CENTRE (NTAMC)

i. The emphasis on the power sector to ensure the growth in GDP has brought in many changes in the business environment of Power Sector. The transmission sector being the integral part of is also facing multiple challenges like competitive bidding for transmission project, lack of experienced manpower, stringent demands by the regulator etc.

ii. The technological development couple with falling prices of communication system and information technology provides us the opportunity for virtual manning of Substation thereby optimizing the requirement of skilled manpower and managing the asset with the available skilled workforce.

iii. Thus, state of the art computerized control centers NTAMC & RTAMC with associated telecommunication system and adapted substation for enabling remote centralized operation, monitoring and control of POWERGRID Transmission system has been proposed.

iv. The aim is to have completely unmanned substation except security personnel. The operations of the substations will be done from a remote centralized location i.e. NTAMC. The RTAMC will co-ordinate the maintenance aspect of the substation from a centralized location and will act as a backup to the NTACM for operation. The maintenance activities would be carried out by maintenance service hub (MSH). One MSH will cater to the requirements of 3-4 substations in its vicinity in coordination with the respective RTAMCs.

v. The substations and various control centers will be connected by redundant broadband communication network through POWERGRID (Telecom) communication links.

vi. Telecom Department to provide high speed communication links between NTAMC, RTAMCs and Sub-stations.

vii. The Connectivity Status has been finalized in association with LD&C department and NTAMC group. More links have to be planned by LD&C for total protection. Bandwidth requirement and Connectivity Scheme finalized. At stations where this connectivity is not possible, leased lines will be hired from other telecom operators up to the nearest connection point.

viii. Total 192 Substation connectivity will be planned in 2 phases.

* Phase-I 120 Sub Stations
* Phase-II 72 Sub Stations

POSOCO:

Power System Operation Corporation Limited(POSOCO) is a wholly owned subsidiary of Power Grid Corporation of India Limited (PGCIL). It was formed in March 2010 to handle the power management functions of PGCIL. It is responsible to ensure the integrated operation of the Grid in a reliable, efficient and secure manner. It consists of 5 Regional Load Dispatch Centers and a National Load Dispatch Centre (NLDC). The subsidiary may eventually be made a separate company, leaving the parent firm with only the task of setting up transmission links. The load dispatch functions, earlier handled by PGCIL, will now come up to POSOCO.

They maintain 99.9% of online without interruption of power supply to the grid, even at worse cases.

POSOCO mainly comprises -
*National Load Despatch Centre (NLDC)
*Five Regional Load Despatch Centre
*Northern Regional Load Despatch Centre (NRLDC)
*Western Regional Load Despatch Centre (WRLDC)
*Eastern Regional Load Despatch Centre (ERLDC)
*Southern Regional Load Despatch Centre (SRLDC)
*North-Eastern Regional Load Despatch Centre (NERLDC)

POWER GRID transmission network failure:

The Northern Region Grid, which provides power to nine states in northern India including Delhi, experienced a widespread outage due to a grid disturbance that occurred at about 2.35 a.m. on 30 July 2012.

Restoration work started immediately under the direction of CEO, POSOCO and POWERGRID's Chairman & Managing Director. A team of engineers tried to find out a way for restoring the normal supply of power immediately, so that railways, Metro, airports and other power users deemed essential could get immediate restoration of electricity. With the coordinated efforts of the whole team of engineers and constituent state utilities, power supply to the essential services and other essential loads in northern India was restored by about 8.00 a.m. and about 60% of load of the Northern Region was restored by 11:00 a.m. This was possible by gearing up the power supply from hydroelectric sources and also extending power from the Eastern and Western regions for start-up supply for thermal generating units of the Northern Region. Thus the associated problems for want of power supply could be partially overcome by this time. Later, power supply was restored progressively and by 12:30 p.m. power was extended to most of the cities and towns through POWERGRID substations. The Northern Grid was brought back to normalcy to meet the demand of about 30 GW at 7:00 p.m.
On 31 July 2012, the northern grid collapsed for a second time, hours after the power supply was restored in the entire northern region following a disruption on the previous day. The eastern transmission lines also failed, disrupting power supply in Delhi, Uttar Pradesh, Haryana, West Bengal, Assam and Punjab, among other states.

Energy distribution:

An electric power distribution system is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltageranging between 2 kV and 35 kV with the use of transformers.

Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage of household appliances and typically feed several customers through secondary distribution lines at this voltage. Commercial andresidential customers are connected to the secondary distribution lines through service drops. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub transmission level.

Overview of the Existing System:

The distribution segment continues to carry electricity from the point where transmission leaves off, that is, at the 66/33 kV level. The standard voltages on the distribution side aretherefore 66kV, 33 kV, 22 kV, 11 kV and 400/230 volts, besides 6.6 kV, 3.3 kV and 2.2 kV. Depending upon the quantum of power and the distance involved, lines of appropriate voltages are laid. The main distribution equipment comprises HT and LT lines, transformers, substations, switchgears, capacitors, conductors and meters. HT lines supply electricity to industrial consumers while LT lines carry it to residential and commercial consumers.

State-Of-The-Art SCADA/EMS System:

SCADA system which is the sensory organ of grid operator measures vital systemvariables through RTU (Remote terminal Unit) or SAS (Substation automation system)installed at all the important locations in the grid. The recorded data is transmittedthrough modern communication channels and displayed in the operator consoles inload dispatch centers. It provides real time control and monitoring of energymanagement facilities to optimize system reliability, load dispatch, voltage control,system restoration, switching operations, planned maintenance outage, datarecording, load flow, analyses of existing & future system conditions and therebyoptimize operation to each constituent in particular and the Region as a whole.

Effective visualization techniques and tools are used to empower the system operatorin facilitating quick response under critical conditions. Techniques used by the Indiangrid operators are Tabular presentation, Bus Diagrams, Flow gate Illustration, ControlArea – Tie Line Representation, Geographical Displays, Contouring, ThreeDimensional Representations, and Animation.

Smart Grid:

The complexity of Grid is increasing continuously due to Growing number ofinterconnections within and across the regions. The real time information availabletoday through conventional SCADA/EMS system is limited to analog and status datafrom the remote terminal units. Information, such as indications of protective controlactions, event/fault records, device settings are not available. System dynamics arenot taken in real time evaluations. Emergency controls such as load shedding do notconsider system-wide conditions. Protective relay settings are static – no intelligenceis embedded to allow adaptation to the changing system conditions

To take care of above complexities and to ensure safe, secure and reliable operationof large interconnected Indian Grid, system operation in future would be equipped withan

Intelligent/Smart Grid with placement of Phasor Measurement Unit, Wide AreaMonitoring, Self-Healing, and adaptive islanding features etc. with an intent to quicklyevaluate system vulnerability with respect to cascaded events involving faults, devicemalfunctions and provide remedial action.

Initiatives have been taken to implement Smart Grid pilot projects for grid security ofIndian grid.

(a) Implementation of Pilot project for installation of PMUs (Phasor MeasurementUnits) in Northern Region

(b) Implementation of CSIR approved Project "Intelligent Monitoring & Control ofthe Interconnected Electric Power Grid using WAMS.

To keep track of new technology & development POWERGRID is also a member ofInternational group VLPGO (Very Large Power Grid Operators) with other internationalutilities .VLPGO is a common platform where worldwide large Grid Operators cometogether for mutual benefit, sharing common problems and solution.

III. Conclusion

The regulatory environment is steadily moving towards increasing competition in the electricity market allowing several new players in addition to traditional utilities and independent power producers such as captive power producers, merchant power producers, renewable energy generators, etc., on the one hand and customers requiring access to the grid on a nondiscriminatory basis on the other. With full open access in the distribution segment, the consumer will no longer be captive to one discom but will have greater choice in getting power from any of the new entities connected to the grid. If the smart grids are implemented very effectively in India, it will be very useful to meet out the power demands. The regulatory environment too has now become stable with multi-year tariffs becoming a norm in states.

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